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B DECAYS ON THE LATTICE AND RESULTS FOR PHENOMENOLOGY

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Lattice Monte Carlo simulations now include the effects of 2 light sea quarks and 1 strange sea quark through the use of an improved staggered fermion action. Consequently, results important to phenomenology are free of the approximate 10% errors inherent in the quenched approximation. This talk reports on calculations of the B and B_s decay constants and $B \rightarrow \pi \ell \nu$ form factors. Accurate determinations of these quantities will lead to tighter constraints on CKM matrix elements.

Keywords: Lattice QCD; B meson decays; CKM parameters

1. Introduction

Lattice QCD results for hadronic matrix elements governing neutral K and B mixing are important elements in the quest to determine the CKM parameters $\overline{\rho}$ and $\overline{\eta}$.[1] *Ab initio* calculations of form factors for K, D, and B exclusive semileptonic decays can be combined with experiment to obtain CKM matrix elements, complementing other determinations, e.g. through inclusive decays. Furthermore, many of the lattice calculations in the charm sector will be testable at current experiments, notably CLEO-c.[2]

The effects of light sea quark masses are now included in present state-of-the-art lattice simulations. The first round of results showed that cleanly computable, or "golden," quantities agree with experiment within the few percent lattice uncertainties.[3] This is in sharp contrast to quenched lattice calculations, which

neglect sea quark effects and have 10-20% discrepancies. Having shed the quenched approximation and its errors, lattice calculations are in a position to make an even greater impact on flavor phenomenology.

This talk briefly summarizes our recent work on the B and B_s decay constants and the form factors describing $B \to \pi \ell \nu$ decay.

2. Decay Constants

The B_s decay constant is straightforward to compute since no extrapolations in the valence quark masses are needed. We recently computed it to be[4]

$$f_{B_s} = 260 \pm 7 \text{ (stat)} \pm 28 \text{ (sys) MeV}. \tag{1}$$

This represents the current state-of-the-art because effects of 2 light and 1 strange sea quarks are included. The dominant systematic uncertainty is estimated to come from higher order terms in the perturbative matching of lattice NRQCD to continuum QCD.[5] Prospects for reducing that uncertainty lie in a future 2-loop matching calculation or a partially nonperturbative estimate.

The calculation of f_B requires significantly more work. The light quark mass extrapolation is done using chiral perturbation theory; however, the simulations must be performed at light enough masses that the leading order terms are sufficient. Fig. 1 (left) shows our progress computing f_B. We vary both the valence and sea quark masses which will permit a partially quenched analysis.[6] Recent work has focused on techniques to improve the signal-to-noise ratio for the correlation functions we compute.[7] The leftmost 2 points in Fig. 1 (left) illustrate a dramatic improvement in statistical resolution. The large uncertainty due to perturbative matching will cancel in the ratio f_{B_s}/f_B, allowing us to tighten the $|V_{td}|$ constraint.

3. Semileptonic Form Factors

We recently presented preliminary results for the $B \to \pi \ell \nu$ form factors.[8] Fig. 1 (right) shows the form factors f_+ and f_0 as functions of momentum transfer. Simulations can presently be carried out only at large q^2. As q^2 decreases, the pion momentum increases and discretization errors which scale like $(p_\pi a)$ become sizable. After extrapolating the light quark mass to its physical value, the form factors are fit well by the Bećirević - Kaidalov ansatz.[9] One can integrate the form factors and combine the result with the B^0 lifetime and the experimental branching ratio for $B^0 \to \pi^- \ell^+ \nu$ to obtain $|V_{ub}|$.[10] The lattice errors can be decreased if the integration in done only over a range of q^2 for which we have data; this result is then combined with the branching ratio for decays with $q^2 \geq 16 \text{ GeV}^2$. Unfortunately applying the momentum cut increases the experimental uncertainty. The preliminary results for both procedures are

$$|V_{ub}| = \begin{cases} 3.86 \pm 0.32 \text{ (expt)} \pm 0.58 \text{ (latt)} \times 10^{-3} & 0 \leq q^2 \leq q^2_{\max} \\ 3.52 \pm 0.73 \text{ (expt)} \pm 0.44 \text{ (latt)} \times 10^{-3} & 16 \text{ GeV}^2 \leq q^2 \leq q^2_{\max} \end{cases} . \tag{2}$$
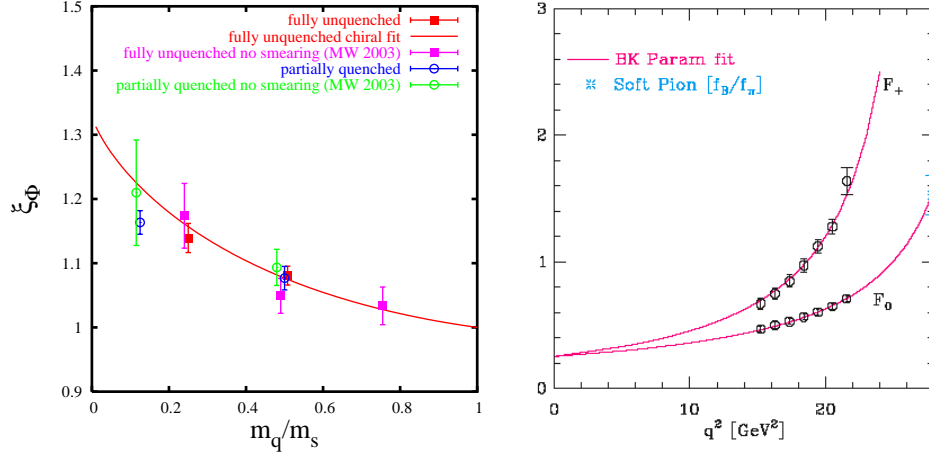
Fig. 1. Left: Progress computing the ratio of decay constants $\xi_\phi \equiv (f_{B_s}\sqrt{m_{B_s}})/(f_B\sqrt{m_B})$; the solid curve illustrates unquenched chiral behavior. Right: Preliminary results for $B \to \pi\ell\nu$ form factors; the data are fit well by the Bećirević - Kaidalov ansatz.

4. Summary

Unquenched lattice calculations with quarks light enough to overlap with the region of validity of chiral perturbation theory will lead to much more accurate results for hadronic matrix elements. The first round of results are already promising. Here we presented results for f_{B_s} and $B \to \pi\ell\nu$ form factors. In the absense of quenched artifacts, we are able to study better the leading systematic uncertainties and find ways to reduce them. Ongoing efforts will lead to more accurate determinations of f_B and the mixing parameters B_B and B_{B_s}.

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